Comparison of PTV+PRV-based Optimization and Robust Optimization in Intensity-Modulated Proton Therapy

Robust optimization leads to IMPT plans that are more robust than and superior in optimality compared to PTV-based optimized plans. Robust optimization incorporates setup and range uncertainties, which implicitly adds margins to targets and organs-at-risk (OARs); whereas PTV-based optimization only considers setup uncertainties and adds margins only to targets. It is interesting to know whether the superiority of robustly optimized plans is due to not assigning margins to OARs during PTV-based optimization.

Figure 1 showed the transverse dose distribution for one H&N case. The dose distribution in the robustly optimized plan was essentially unaffected by the range overshoot compared to the PTV+PRV plan. DVHs of the worst-case dose distribution from robust plan (solid lines), PTV plan (dashed lines), and PTV+PRV plan (dash dot lines) of the same H&N case were compared in Fig. 2. The gap between the DVH curves derived from the highest dose (red line) and the lowest dose (blue line) for the target was used to quantify the plan robustness – the wider the gap, the greater the sensitivity to uncertainty. Robust optimization led to IMPT plans with the most robust doses in both targets and OARs and also the best OAR sparing, while the PTV+PRV-based optimization spared normal tissue better than the PTV-based optimization, although the target dose robustness and homogeneity were comparable from these two methods. $D_{1cc}$ doses for spinal cord and brainstem, mean doses $D_{mean}$ for oral cavity and parotids, $D_{1\%}$ doses for other organs, and $D_{9\%}$ and $D_{95\%}$ doses for the targets from these three different plans were compared in Fig. 3 to assess the plan optimality and target dose coverage and homogeneity for 5 H&N cases. The same conclusion as Fig. 2 was observed. The same conclusions were also observed in the rhabdomyosarcoma case (Fig. 4).

![Figure 1: Comparison of the dose distribution in the transverse plan of an H&N case](image1)

![Figure 2: Comparison of organ sparing and plan robustness of an H&N case via worst-case analysis](image2)

![Figure 3: Comparison of organ sparing and target dose coverage and homogeneity of 5 H&N cases](image3)

![Figure 4: Comparison of organ sparing and plan robustness of a rhabdomyosarcoma case via worst-case analysis](image4)